



Offshore CREYAP Part 2 – preliminary results

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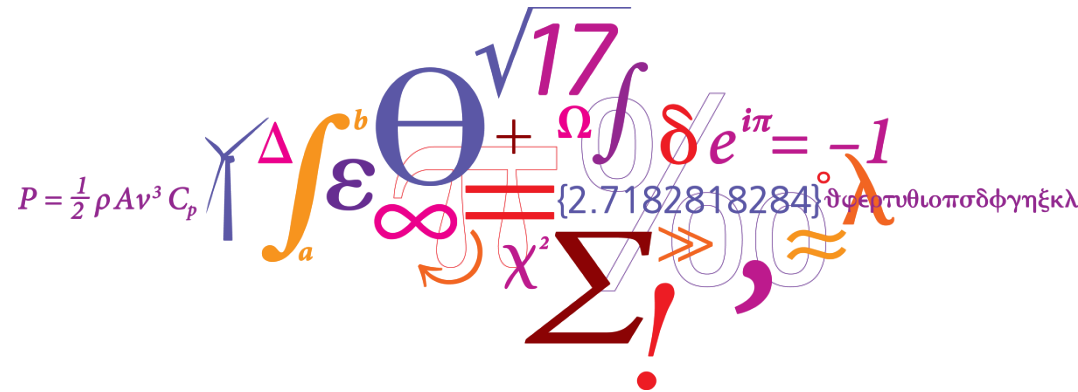
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Offshore CREYAP Part 2 – preliminary results

Niels G Mortensen & Morten Nielsen



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- 22 teams from 8 countries; thanks for making the comparison and presentation possible!
- EWEA team for arranging the 2015 Offshore CREYAP Part 2, thanks to Tim Robinson et al.

Comparison of Resource and Energy Yield Assessment Procedures

EWEA CREYAP concept

- Industry benchmark
- In-house training and R&D
- Identification of R&D issues

Three issues today

- Long-term adjustment
- Wake modelling
- Modelled vs observed yields

CREYAP history

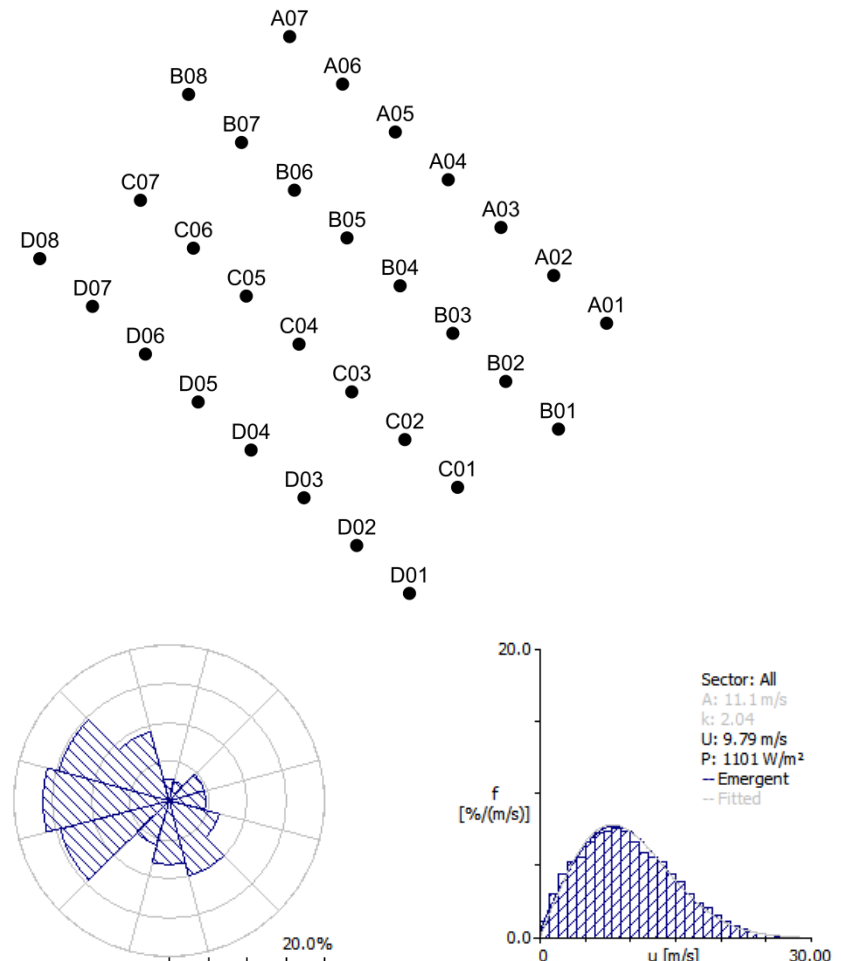
- Onshore Part 1, Bruxelles 2011
 - Scotland, 28 MW, 37 teams
- Onshore Part 2, Dublin 2013
 - Scotland, 29 MW, 60 teams
- Offshore Part 1, Frankfurt 2013
 - Gwynt y Môr, 576 MW, 37 teams
- Offshore Part 2, Copenhagen 2015
 - Barrow, 90 MW, 22 teams

Summary

- 156 submissions from 27 countries

Barrow Offshore Wind Farm

- 30 V90 wind turbines (90 MW)
 - Rated power: 3.0 MW
 - Hub height: 75 m MSL
 - Rotor diameter: 90 m
 - 4 staggered rows, $5.5 \times 8.5 D$
 - Air density: 1.24 kg m^{-3}
 - SCADA: 2008-02 to 2009-01
- Site meteorological masts
 - One 80-m and 50-m mast
 - Wind speed and direction
 - Temperature and pressure
 - Data: 2011-07 to 2012-08
- Auxiliary data
 - MERRA reanalysis 1998-2013
 - Topographical data by choice



Offshore CREYAP II in two parts

Long-term comparisons (10 y)

- Observed wind climate
- Observed turbulence
- Long-term adjustment
- Reference yield
- Gross yield
- Wake effects
- Net yield P50
- Uncertainty estimates
- Net yield P90
- Per-turbine results

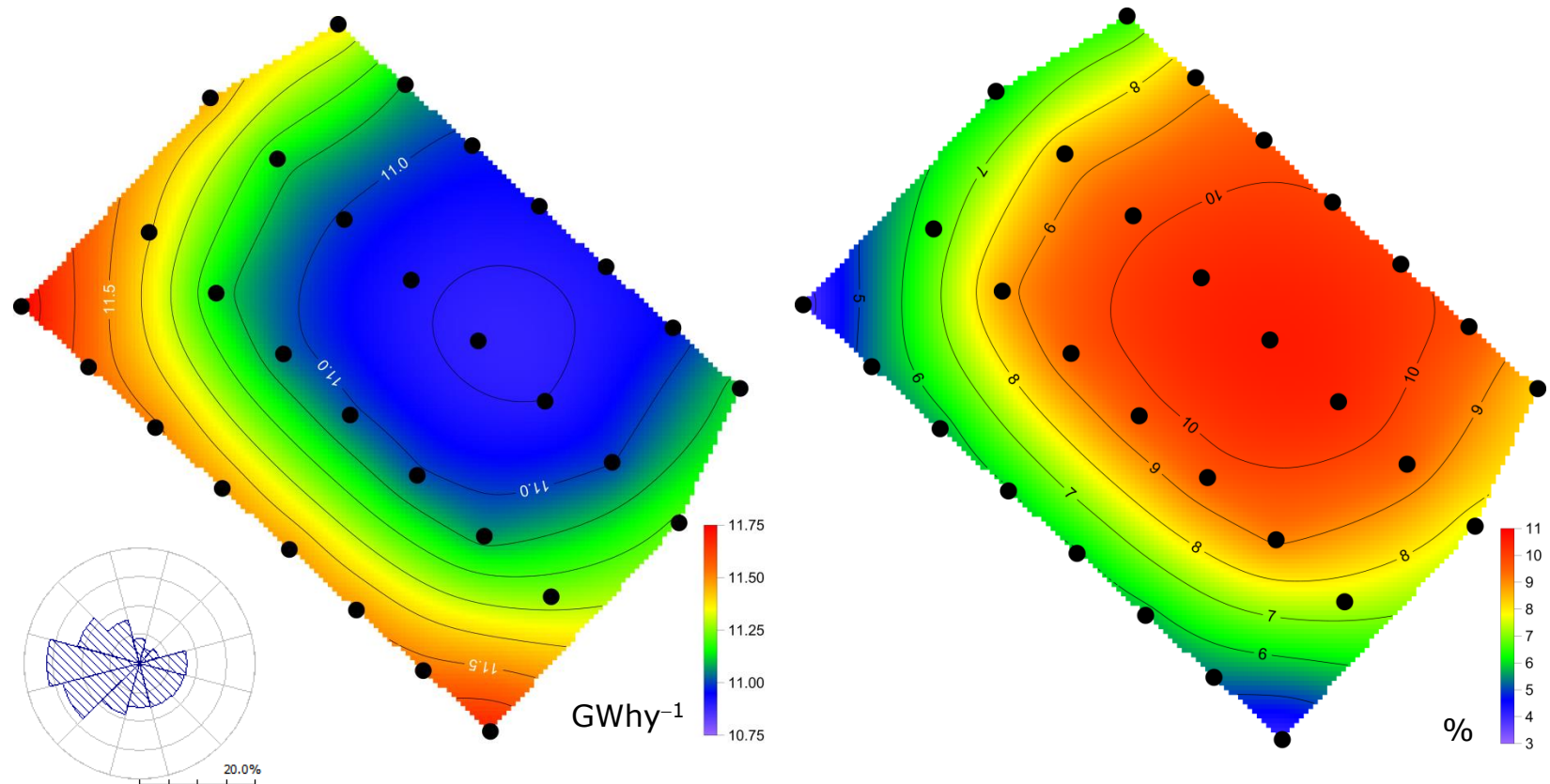
- Team characteristics
- Methodology information

Predicted vs observed yields (1 y)

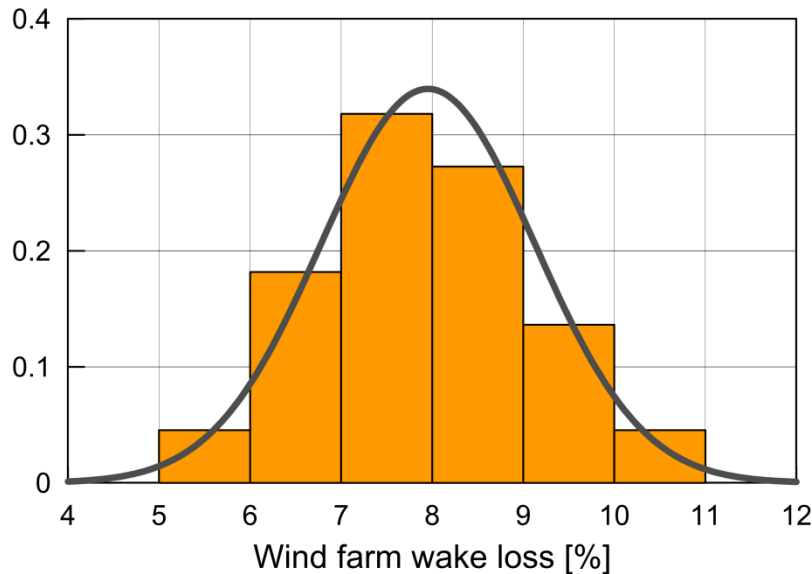
- Reference yield
- Potential yield
- Array efficiency
- Net P50 (losses given)

- SCADA calculation
 - Sum of WTG power readings
 - Curtailment correction
 - Availability correction to 100%
 - Two independent calculations
 - Checked with sub-station meter

Estimated turbine mean yield and wake effect (10 y)



Predicted wind farm wake losses



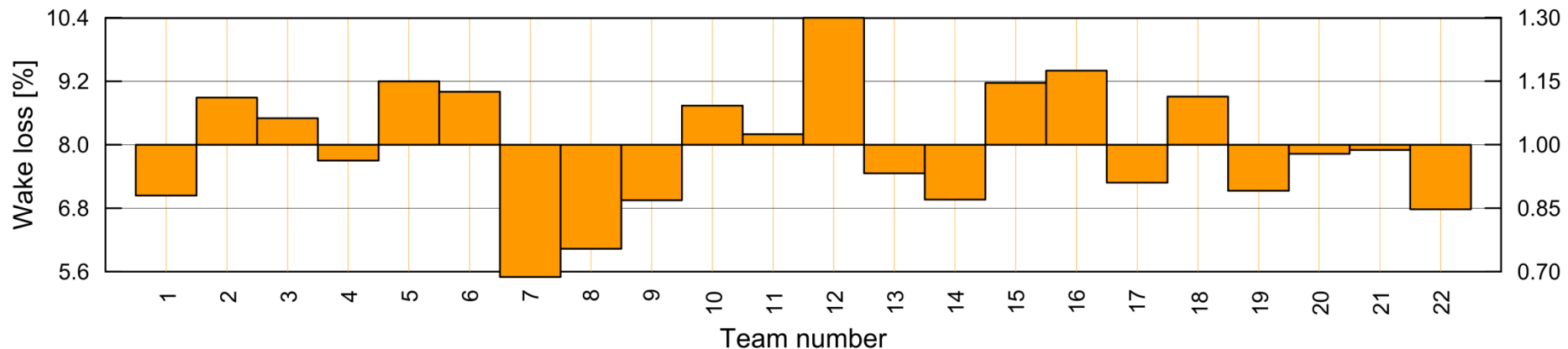
Data points used = 21 (of 22)

Mean wake loss = 8.0%

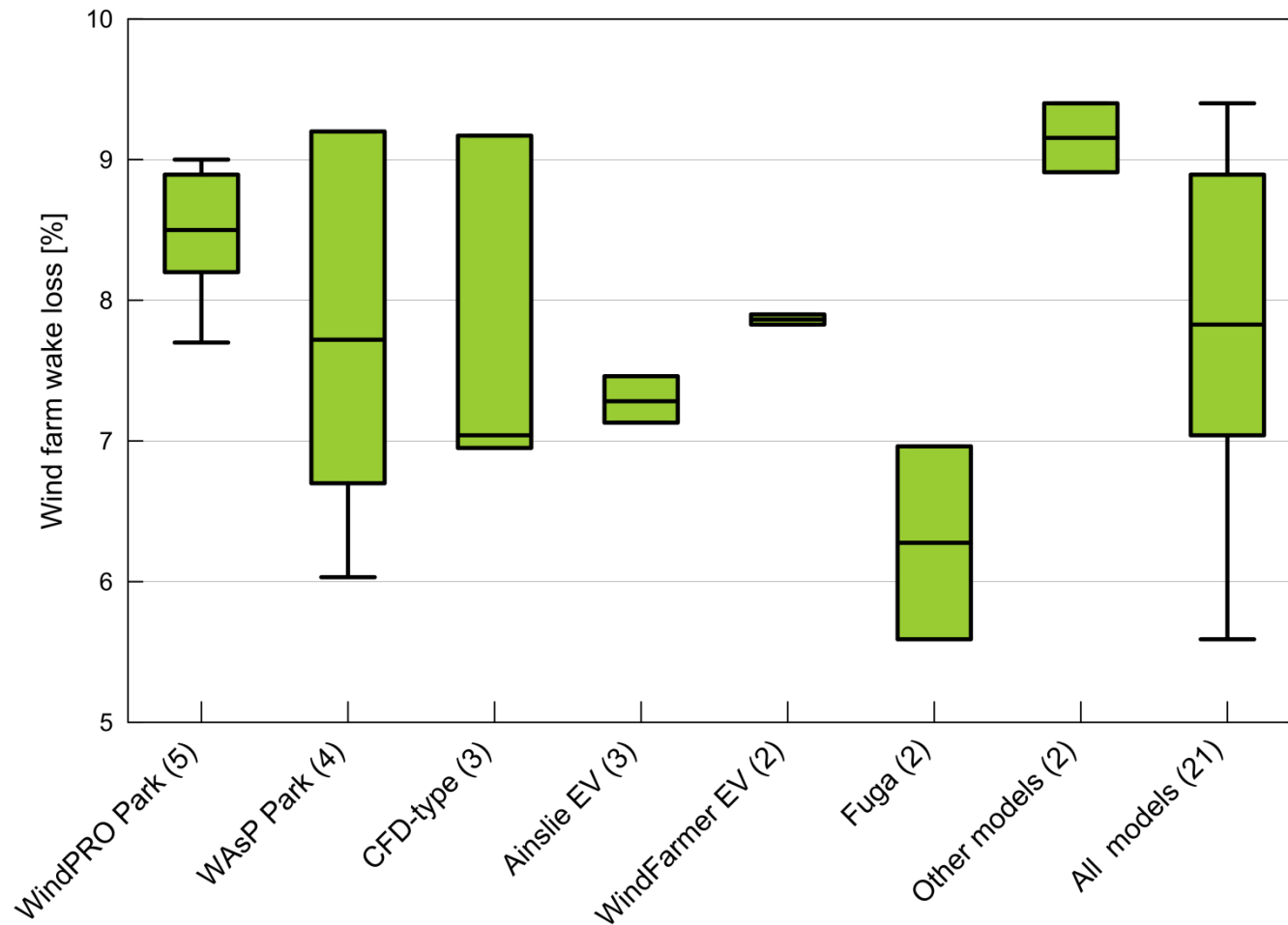
Standard deviation = 1.2%

Coefficient of variation = 15%

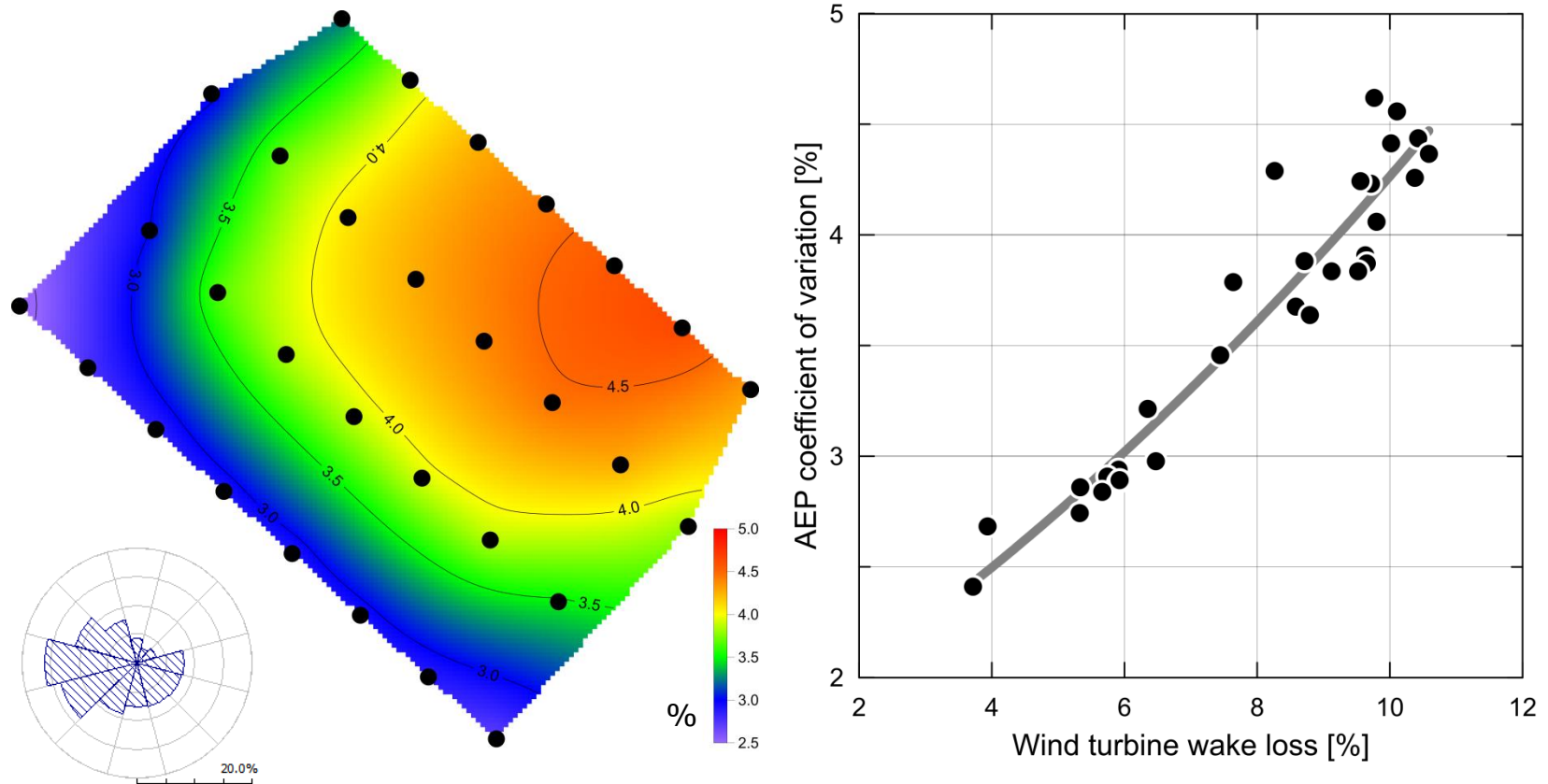
Range = 5.5 to 10.4%



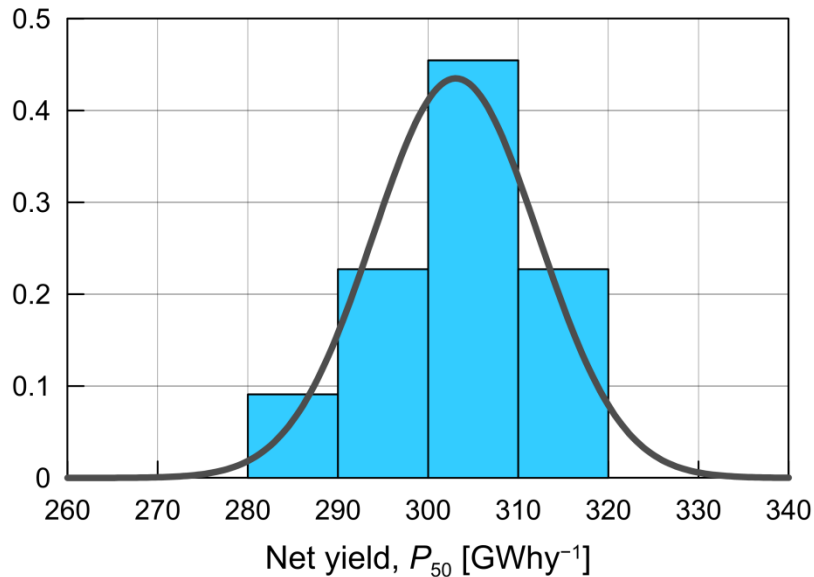
Comparison of wake models



Estimated turbine yields – coefficient of variation



Net energy yield of wind farm, P_{50}



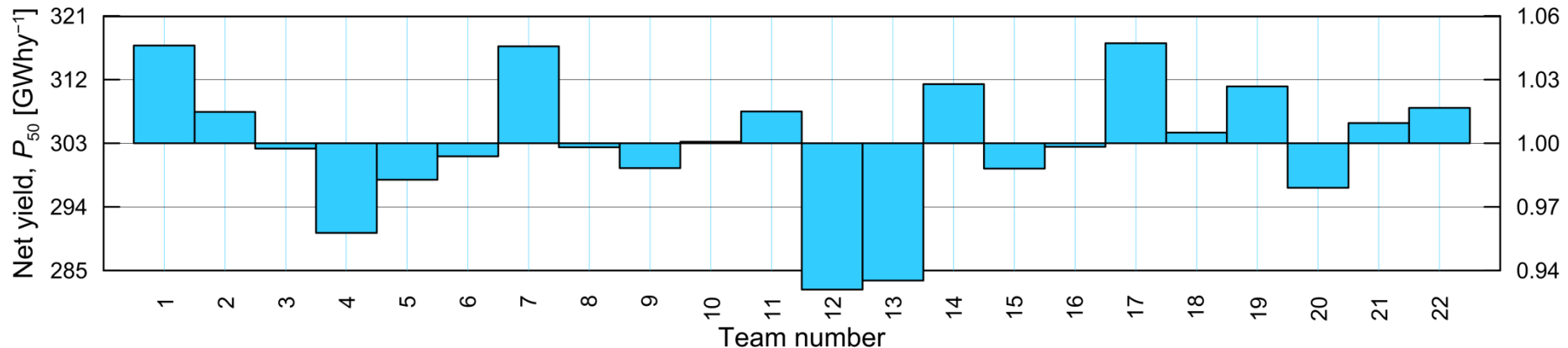
Data points used = 22 (of 22)

Mean net yield = 303 GWh $^{-1}$

Standard deviation = 9.4 GWh $^{-1}$

Coefficient of variation = 3.1%

Range = 282 to 317 GWh $^{-1}$

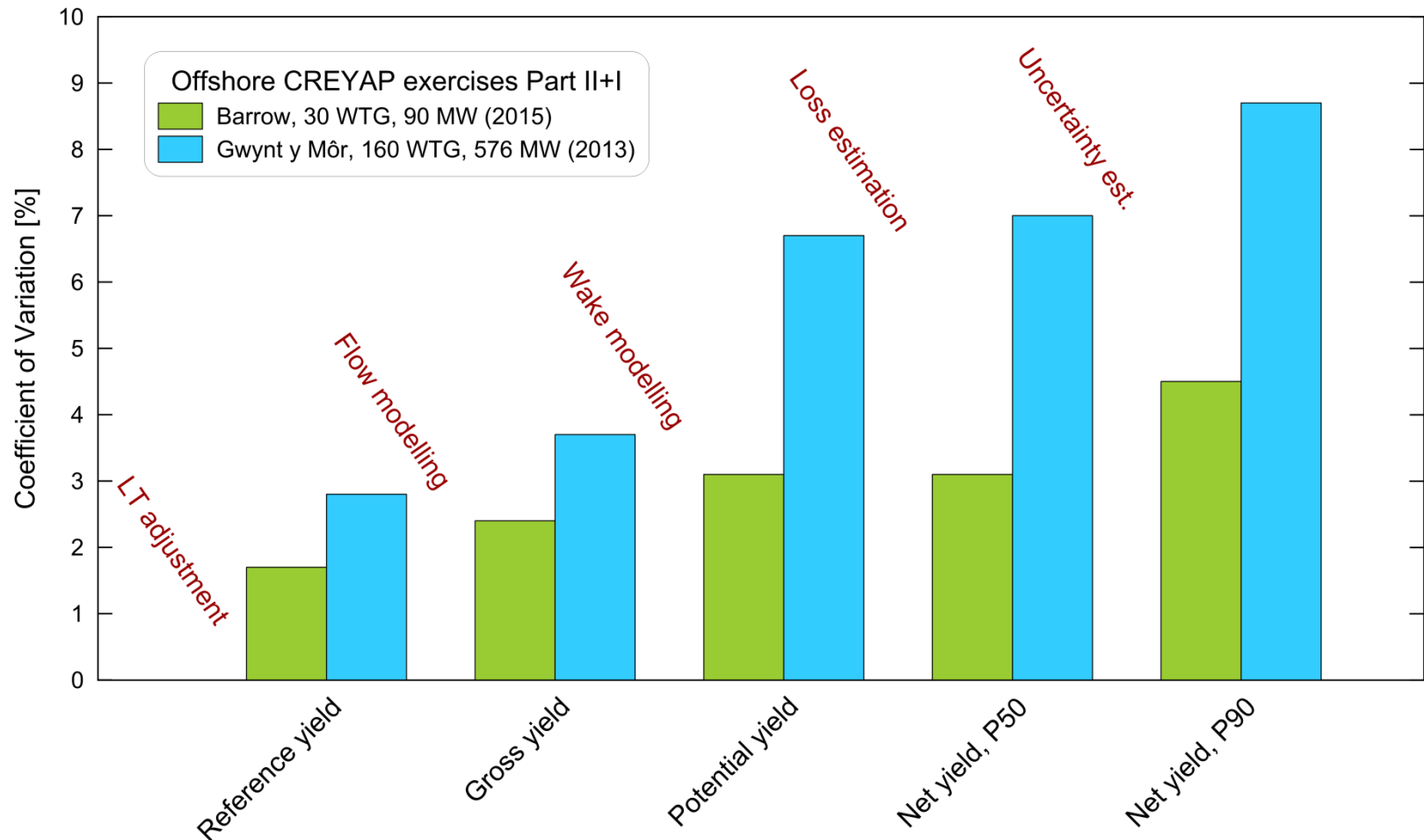


Wind farm key figures – 10-year estimates

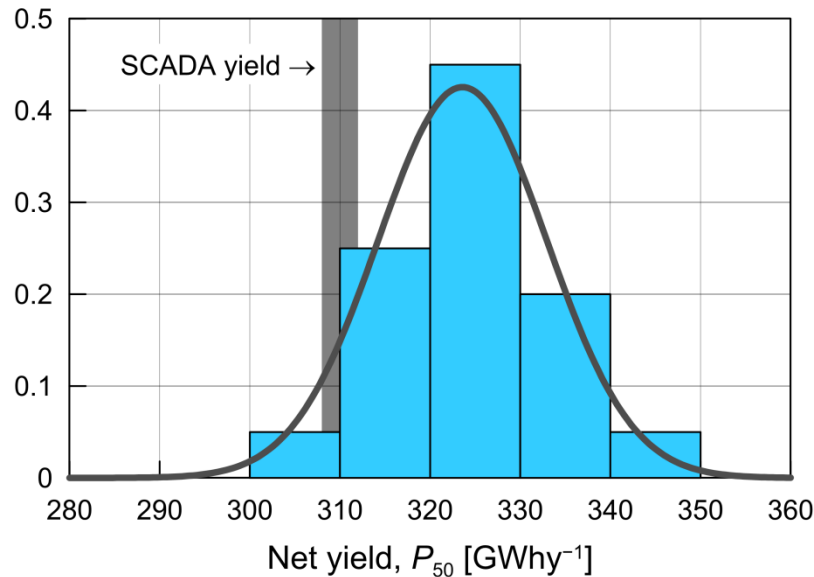
Barrow (10 y)		Mean	σ	CV*	Min	Max
Gross yield	GWh	366	8.9	2.4	338	377
Wake loss	%	8.0	1.2	15.1	5.5	10.4
Potential yield	GWh	334	10.3	3.1	311	350
Technical losses	%	9.3	0.1	1.0	9.2	9.6
Net yield P_{50}	GWh	303	9.4	3.1	282	317
Uncertainty	%	9.7	2.3	23.4	6.1	13.7
Net yield P_{90}	GWh	267	12.1	4.4	245	282

* Coefficient of Variation in per cent.

Spread for different steps in the prediction process



Comparison of predicted to observed P_{50}



Data points used = 20 (of 22)

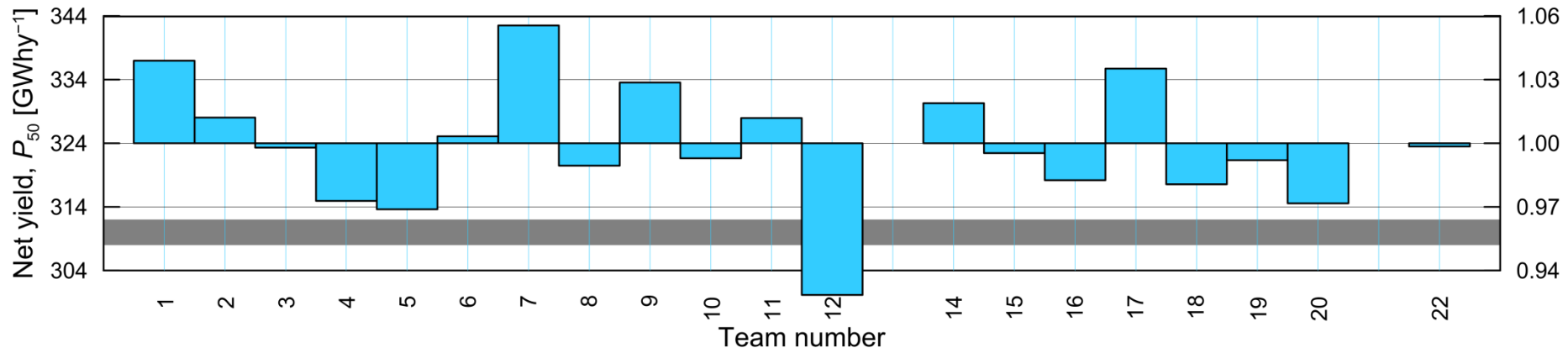
Mean predicted $P_{50} = 324 \text{ GWhy}^{-1}$

Standard deviation = 9.6 GWhy^{-1}

Coefficient of variation = 3.0%


Range = 300 to 343 GWhy^{-1}

Prediction bias = +4%



Summary and conclusions

- Long-term adjustment (applied twice)
 - Average effect = 5.7%, spread = 1.2%
- Wake modelling
 - Average wind farm wake effect = 8%, spread = 15%
 - Wake modelling spread increases with depth into wind farm
- Modelled vs observed 1-y yields
 - Estimated = 104% of observed, spread = 3%
 - Measured yield has an uncertainty too
- CREYAP results seem to improve over time
 - No or fewer outliers in present study
 - Loss and uncertainty calculations improved
- Outlook for future
 - Comprehensive results at EWEA Resource Assessment (June 2015)
 - High-quality wind farm data in high demand for future studies!

A photograph of several offshore wind turbines in the ocean under a clear blue sky. The turbines are silhouetted against the sky, with the largest one in the foreground on the left. The sea is dark blue with some whitecaps.

Thank you for your attention!
More results to be presented at
EWEA Resource Assessment in
Helsinki, 2-3 June 2015